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METEOROLOGICAL OFFICE

Scientific Paper No. 35

A Study of some Aspects of the Climate of the Northern Hemisphere in Recent Years

by D. J. PAINTING, B.Sc.

LONDON: HER MAJESTY'S STATIONERY OFFICE

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A Study of some Aspects of the Climate of the Northern Hemisphere in Recent Years

by D. J. Painting

SUMMARY

A study of climatic variables of the northern hemisphere in recent years has revealed some important changes of trend particularly when comparing the 1970s with the late 1960s. Many of the trends of the 1960s (characterized by excessive blocking in temperate latitudes and a cooling over most of the hemisphere especially in middle and high latitudes) have reversed in the 1970s. In particular it is shown that the Arctic has warmed, Arctic sea ice has decreased and the zonal flow over all latitudes north of 50°N has increased. In the Atlantic sector the centres of the subtropical high pressure belt have moved slightly northwards and the frequencies of blocking anticyclones have declined. Nevertheless measurements of mean annual temperature deduced from surface and 1000-500 mb thickness data show that although the Arctic has warmed north of 60°N a net cooling has occurred since about 1970 over the hemisphere north of 40°N of nearly 0.2 deg.

1 INTRODUCTION

There has been much speculation in literature and the popular press regarding the possibility of the world having entered a period of climatic change leading to a somewhat cooler period in the immediate future with attendant consequences to the community.

The purpose of this study is to examine some aspects of climate in recent years in an attempt to detect any indications of change and to provide a firm basis of fact on which to discuss this important matter. In general, areas to the north of about 40°N have been scrutinized with particular attention to the Atlantic and European sectors. No serious attempt has been made to fit the observations into any theoretical models or to seek theoretical explanations.

The following climatic variables have been studied:

(a) The areas of maximum snow and ice cover of the north polar cap for the period 1965 – 75

(b) The 1000-500 mb thickness anomalies for the period 1951-74 from 90°N to around 30°N.

(c) Arctic temperatures as indicated by selected stations north of 60°N for the period 1960 – 74.

(d) Atlantic sea surface temperatures recorded by the ocean weather station network for the period 1951 – 74 and by ships of the voluntary observing fleet.

(e) Surface pressure anomalies for the period 1960 – 74 for the northern hemisphere.

(f) Zonal flow for the northern hemisphere, for the British Isles and the Atlantic for the period 1900 – 74.

(g) Blocking and subtropical anticyclones in the vicinity of the British Isles for the period 1965 – 74.

2 SNOW AND ICE COVER

Kukla and Kukla (1974) have reported a significant increase in the areas of snow and ice for the northern hemisphere in the 1970s compared with the late 1960s. An analysis based on surface reports for the peak snow-cover months of January and February shows that, apart from the area north of the Himalayas for which data are sparse, there has been no general increase in maximum snow covered area. On the contrary the trend has been for a decrease in the peak area. The snow-limit line was taken from routine snow-depth charts prepared in the Meteorological Office. The area of land covered by at least one inch (25.4 mm) of snow was evaluated by counting degree squares and converting into square kilometres.

The results of the investigations of snow area for January and February are shown in Figure 1, where curves (a) and (b) give the total cover, curves (c) and (d) that for 0-180°E and (e) and (f) for 0-180°W.

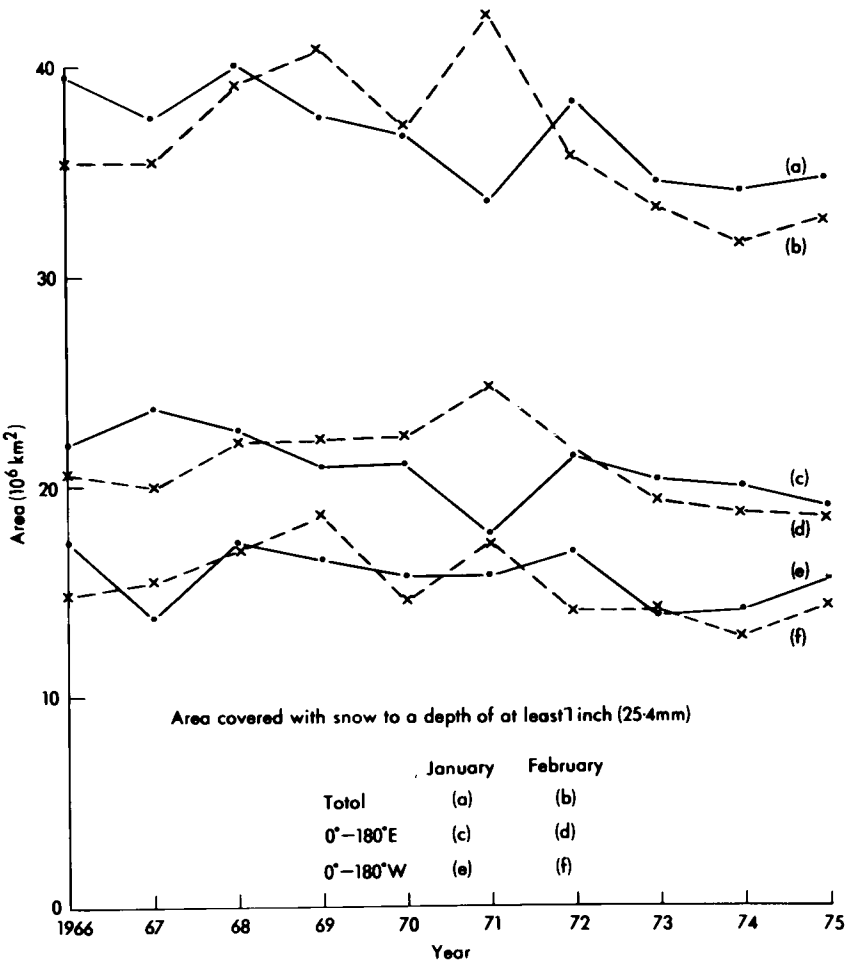

Figure 1. Snow cover in January and February 1966-75 over the Northern Hemisphere (excluding China).

Area covered with snow to a depth of at least 1 inch (25.4 mm).

Recently, Sanderson (1975) has reported a general decrease in the areas of northern hemisphere sea ice. Averaging the February, March, April and September areas with 7/10 or more of sea ice over two consecutive three-year periods, namely 1969-71 and 1972-74, gave mean decreases in the latter period over the former, of 3, 0.3, 3, 8, and 3 per cent for the respective months. The year-to-year variations were generally less than 10 per cent of total area.

The excessive snow and ice cover of the winter of 1971–72 quoted by Kukla and Kukla can be compared with our estimates by adding the sea-ice area (according to Sanderson) to the total snow area for the appropriate month, ie $(15.72 + 38.21) \times 10^6$ km^2 plus an additional area to the north of the Himalayas. This amounts to an extra 12.52×10^6 km^2 given by extending the snow boundary of our original analysis to the line given by Kukla. The revised total area then amounts to 66.45×10^6 km^2 which shows remarkable agreement with the figure derived from satellite data by Kukla and Kukla (66.7×10^6 km^2 on 10 February 1972). A study of synoptic charts available for the appropriate period revealed several stations reporting moderate snowfall in the Tibetan Plateau region thus tending to verify the satellite data. There has been little sign since 1972 of large snowfalls in this critical region and it is clear that there is insufficient knowledge as to the 'normal' year-to-year variability of snow cover, particularly in the very large region to the north of the Himalayas. It is suggested that the variability of the total area due to occasional snowfalls north of the Himalayas can easily amount to some 15 per cent. In view of the relatively short period of time for which good satellite data have been available and bearing in mind the difficulties of interpretation (World Meteorological Organization, 1973) it is considered that any attempts to fit trends to existing data are premature and unlikely to provide useful indications of future climatic regimes.

3 THICKNESS ANOMALIES

There can be no doubt that a study of 1000–500 mb thickness reveals a more or less steady decrease for the period since 1950 for the area to the north of 45°N. In Figure 2 the mean annual anomalies with respect to the 1949–73 normals are shown in 5° latitude bands and the 5 year running means for the bands 80°N, 70°N, 60°N, and 50°N are illustrated in Figure 3. In recent years (since about 1965) it is apparent that a general rise has occurred in the more northern bands. The seasonal variations over the same period for the polar cap north of 47½°N are shown in Figure 4. Noteworthy features are the generally warmer winters in the later years with all other seasons showing general fall from the early 1950s. Springs and summers have however recovered somewhat since the mid 1960s. These results closely agree with those of Dronia (1974) who has produced a comprehensive analysis of northern hemisphere temperature based on 1000-500-mb thickness data. Thickness anomaly maps covering the period 1961–74 have been computed from the 1957–70 normals and a comparison made between the 1971–74 period and the 1961–70 period by mean seasonal and mean annual differences. These difference maps show clearly the recent trends in mean air temperature in the lower layers of the atmosphere in the northern hemisphere generally north of 40°N. The annual map (Figure 5) shows a positive (warm) area extending from northern Europe over the north pole into Siberia. Otherwise the differences are generally negative (cold). Averaging the differences latitude by latitude at 5° intervals demonstrates the overall effect which is illus-

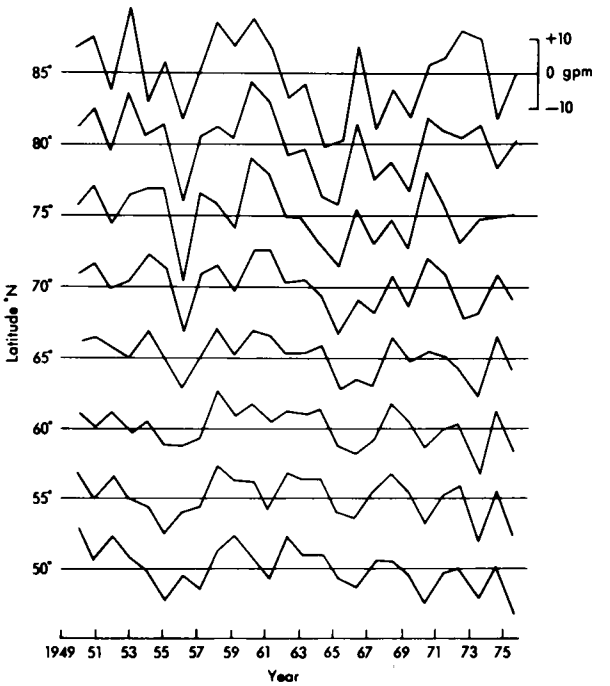

Figure 2. 1000-500 mb thickness. Northern Hemisphere.
Mean annual departures from 1949-73 averages (gpm).

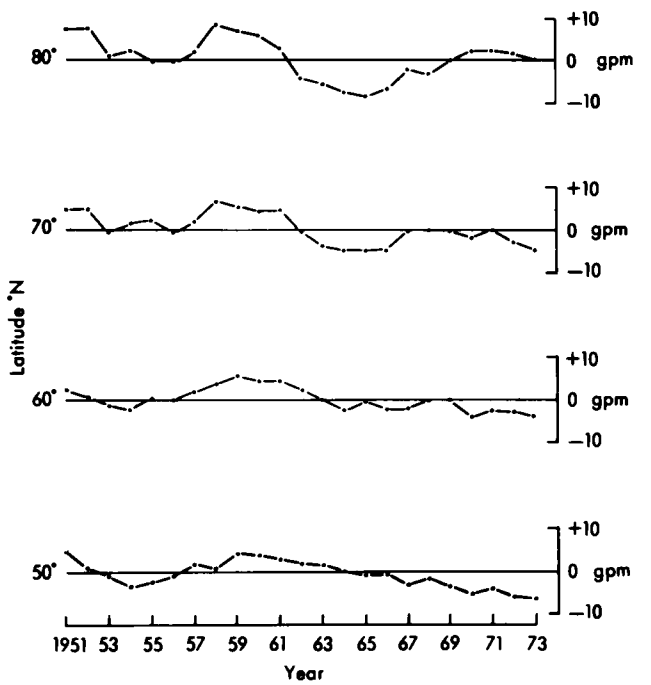

Figure 3. 1000-500 mb thickness. Northern Hemisphere.
5-year running means of annual departures from 1949-73 averages (gpm).

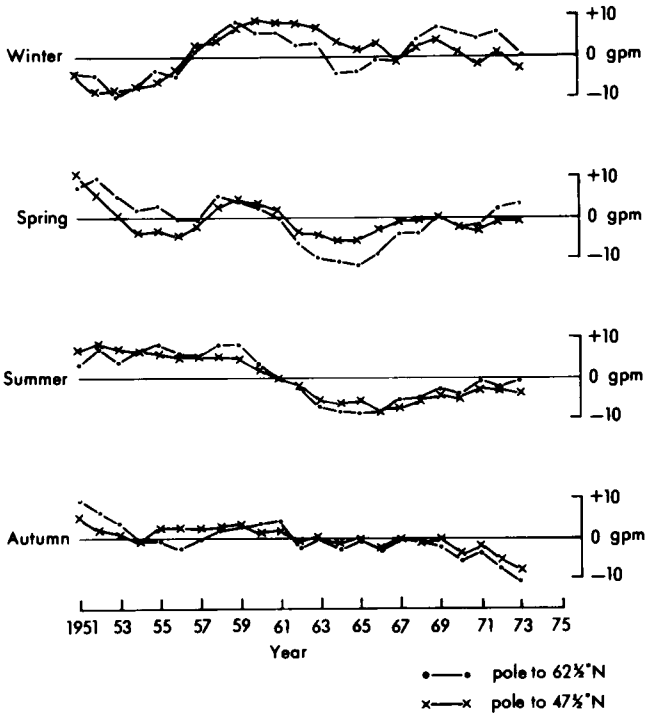

Figure 4. 1000-500 mb thickness. Northern Hemisphere.
5-year running means of seasonal departures from 1949-73 averages (gpm).

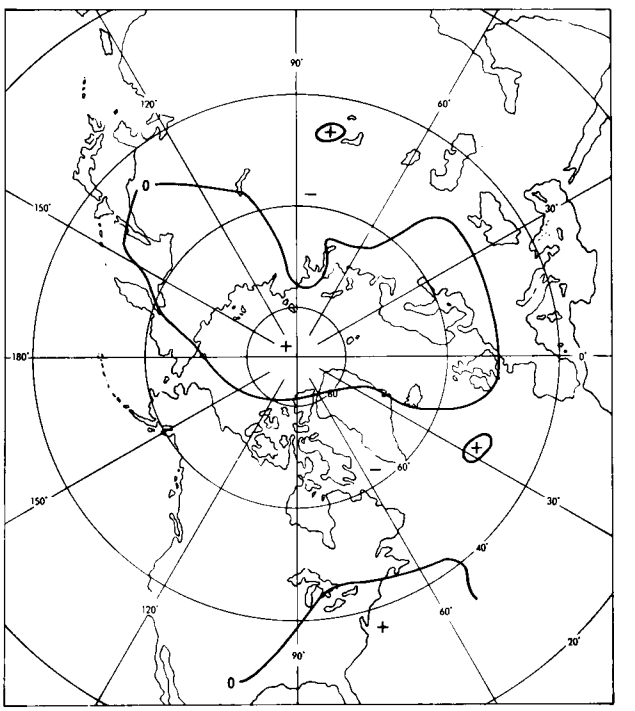

Figure 5. 1000-500 mb thickness. Northern Hemisphere. Year.
Difference of averages, 1971-4 minus 1961-70, (gpm).

trated in figure 6. Weighting the means according to the area of each band and averaging over the total area gives an equivalent temperature difference of −0.17 degC. Here we are using the formula

$$\Delta H = 29.3\ \Delta T \log_e(p_1/p_2)$$

where ΔH = thickness anomaly (gpm), ΔT = mean air temperature anomaly (degC), and p_1, p_2 = boundary pressures (500, 1000 mb). A useful approximation from this formula gives

$$1 \text{ deg} = 20 \text{ gpm}.$$

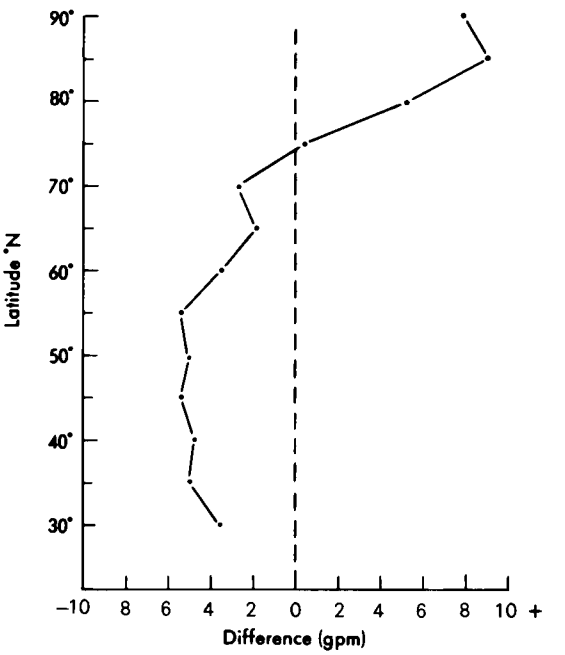

Figure 6. 1000-500 mb thickness. Northern Hemisphere. Year.

Difference of averages by latitude band, 1971-4 minus 1961-70, (gpm).

Winter differences (Figure7) are similar to, and in fact dominate, the annual pattern, thus the positive area is enhanced with a centre of some +3 deg with similarly depressed cold zones. The hemispheric average difference (to the north of 30°N) calculated in the same fashion as the average annual difference is equivalent to some −0.24 deg. Again the springs (figure 8) have a positive area covering the British Isles and northern Europe extending over the north pole and Siberia. Warm areas are also evident over Canada and the western Atlantic Ocean. A belt of cooler air is noted generally in the zone from 40°N to 50°N. The average around each band is slightly negative giving a small mean negative equivalent temperature difference.

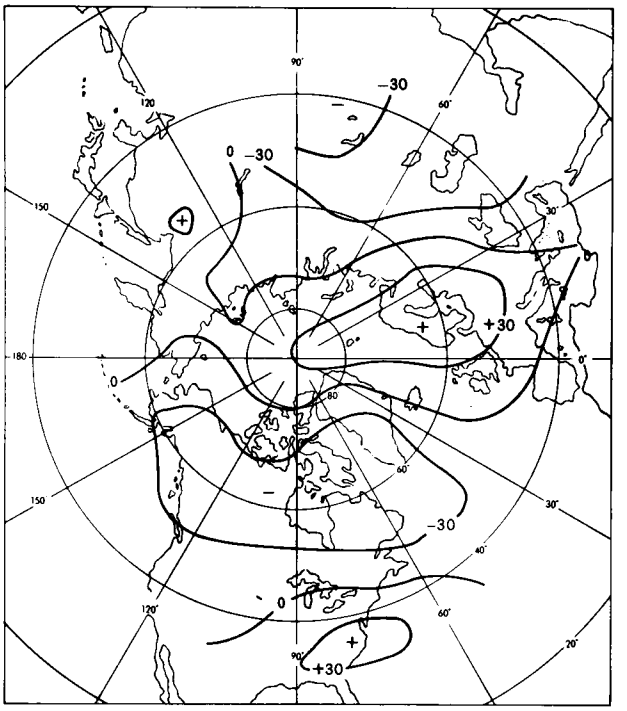

Figure 7. 1000-500 mb.thickness. Northern Hemisphere. Winter. Difference of averages, 1971-4 minus 1961-70, (gpm).

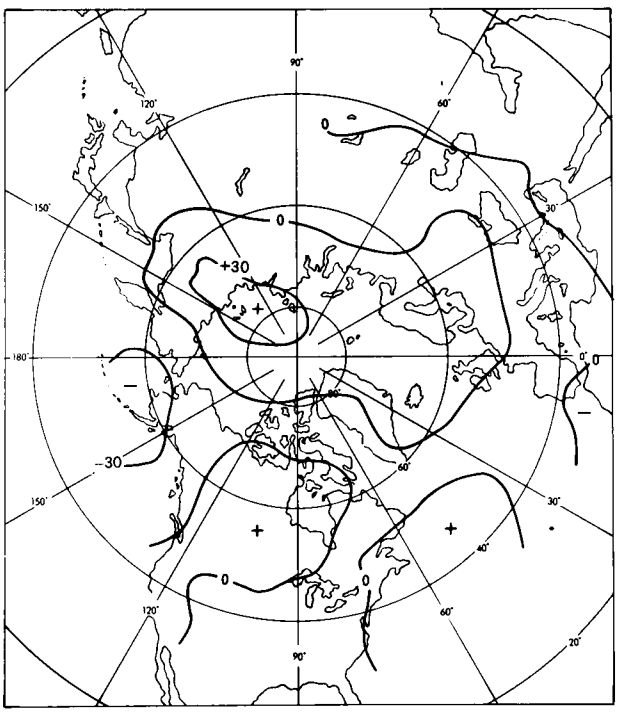

Figure 8 1000-500 mb thickness. Northern Hemisphere. Spring. Difference of averages, 1971-4 minus 1961-70, (gpm).

Summer differences are shown in Figure 9. Here we note a marked change in the distribution of cool and warm regions. The north pole has become relatively cool with a surrounding warmer area with the exception of a negative band stretching from the vicinity of the Iberian Peninsula through the British Isles into Greenland and the Davis Strait. The differences are rather small (everywhere less than the equivalent of 1 deg) and the hemispherical average (north of 40°N) is close to zero whereas in the autumns (Figure 10) the negative areas dominate with positive areas in mid Atlantic and central eastern United States and a positive band extending from the Caspian Sea through central Asia to the Aleutians. The averages around each latitude band in autumn are all negative and the hemispherical average north of 40°N is equivalent to some −0.36 deg. Figure 11 shows the seasonal average differences by latitude bands showing clearly the contrast between winters and springs on the one hand and summers and autumns on the other.

To confirm the evidence of overall cooling at the surface in the mid latitudes a check was made of mean air surface temperatures for some 20 stations in the band 50° to 60°N. When weighted according to area, and averaged, a net cooling of 0.2 deg resulted in the period 1971–74 with respect to the 1960s. The equivalent thickness-derived figure is 0.23 deg.

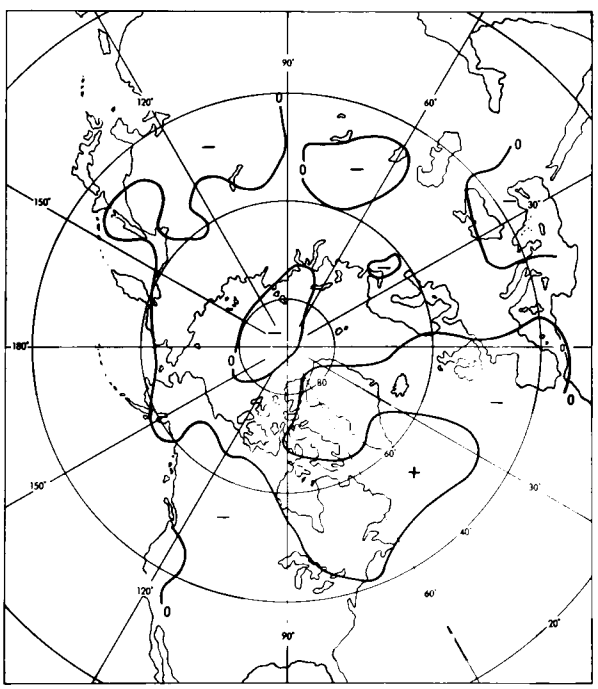

Figure 9 1000-500 mb thickness. Northern Hemisphere. Summer.
Difference of averages, 1971-4 minus 1961-70, (gpm).

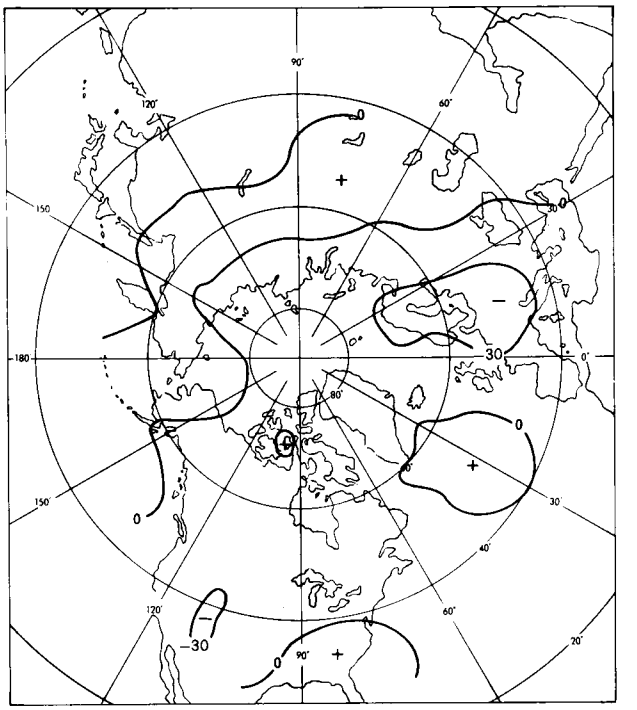

Figure 10. 1000-500 mb thickness. Northern Hemisphere. Autumn.

Difference of averages, 1971-4 minus 1961-40, (gpm).

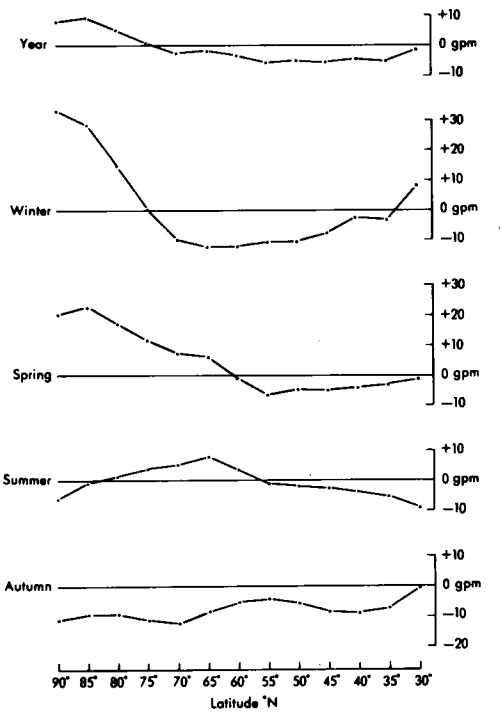

Figure 11. 1000-500 mb thickness. Northern Hemisphere.

Annual and seasonal differences of averages by latitude band, 1971-4 minus 1961-70, (gpm).

4 ARCTIC TEMPERATURES

Monthly and annual surface temperatures have been analysed for 18 stations north of about 60°N and a map of the annual temperature differences (1971–74 minus 1961–70) is shown in Figure 12. The average difference round latitude 70°N is slightly positive confirming the tendency revealed by the 1000–500 mb thickness analysis referred to in the previous section. The colder areas are mainly confined to the North Alaskan region, west Beaufort Sea and Baffin Bay. Central northern Canada and a broad band extending from northern Europe over the north pole into eastern Siberia show positive temperature differences with a maximum of nearly +2 deg near Spitsbergen. In view of the close agreement with equivalent temperatures apparent from the total thickness differences (see Figure 5) a composite temperature difference map has been derived using thickness/surface temperature relationships obtained by regressing mean surface temperature data for the 18 stations round the northern hemisphere north of 60°N on the equivalent values of mean total thickness. The resulting values of mean temperature difference are weighted linearly according to the proximity of a surface observation to give the temperature difference map of Figure 13. The mean temperature difference of the period 1971–74 minus the period 1961–70 north of 60°N calculated from the values on Figure 13 amounts to +0.21 deg.

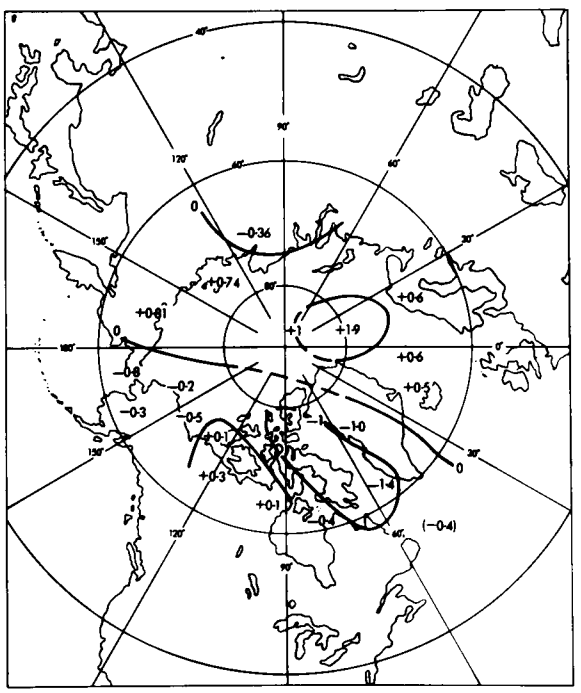

Figure 12. Arctic temperature. Year.

Difference of averages, 1971-4 minus 1961-70, (deg).

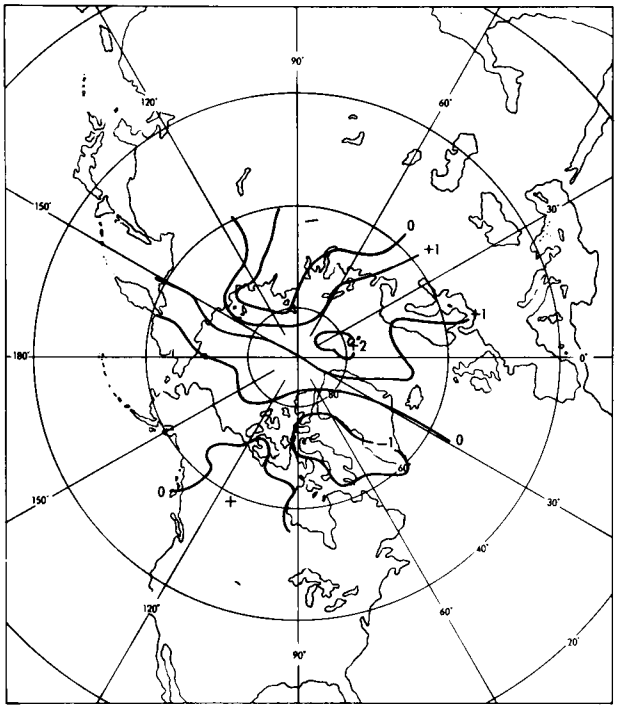

Figure 13. Arctic temperature. Year.

Difference of averages derived from surface temperature and 1000-500 mb thickness, 1971-4 minus 1961-70, (deg).

5 ATLANTIC SEA SURFACE TEMPERATURES

The North Atlantic Ocean Station temperature data for the period 1951–74 have been scrutinized to verify the large drops in sea surface temperature indicated by Rodewald (1972), Teich (1971), Wahl and Bryson (1975), and Perry (1974). It is probable that the averaging of temperatures from the nine ocean weather ships gives a false impression of trends of sea surface temperature in recent years since the main contribution to the measured fall has been at station D. However, analyses of the temperatures at stations I, J, K, and M to the end of 1974 indicate a general cooling trend for the past 15 years. To put these measurements into perspective Ratcliffe (1974) has analysed sea surface temperature data in the vicinity of station D for the period 1886–1973. The results are summarized in Figure 14 which shows a slow erratic rise of sea surface temperature from about 1900 to 1936 probably representing the westerly epoch, a peak in the period 1950–55 followed by a rapid decline from 1955 to 1957 since when the temperatures have remained fairly constant. In general there would appear to be no secular trend over the complete period, but the period 1950-55 stands out as one of exceptional warmth. Changes since 1957 have been rather small and well within the normal variability.

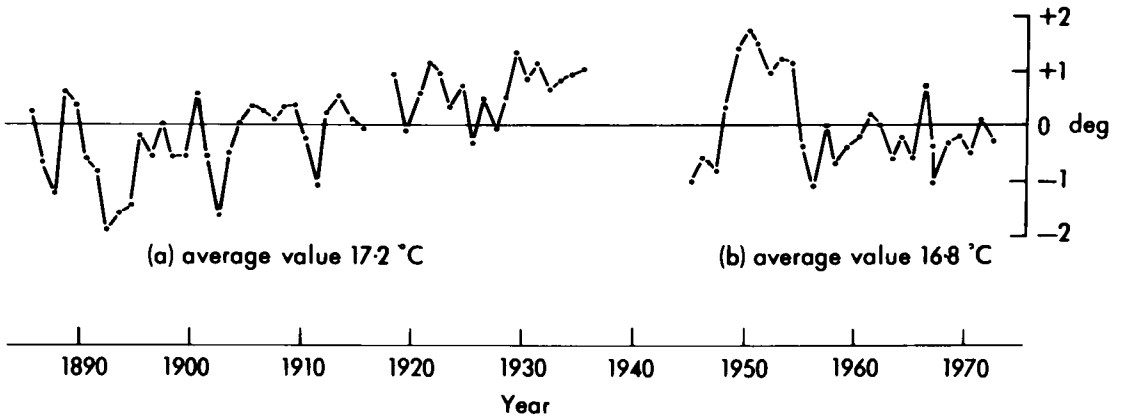

Figure 14. Atlantic sea surface temperature.

Differences from average (deg): (a) 40° – 45°N, 40° – 45°W, 1886-1936.
(b) at ocean station D (44°N, 41°W), 1946-73

6 SURFACE PRESSURE ANOMALIES

Annual anomaly maps have been drawn for the period 1961–74 and mean seasonal and mean annual differences for the period 1971–74 minus 1961–70. The year-to-year variations appear largely random with few significant departures from the normal pattern (the standard deviation of annual means for each grid point varies from about 1 mb in low latitudes to about 2 mb near the pole). Of the earlier years 1967 is the most unusual with a marked negative anomaly of some −7 mb near the pole. As regards the differences between the 1970s and the 1960s a clearer picture emerges. The annual chart (Figure 15, drawn at 2-mb intervals which gives areas of near 2σ pressure difference) shows lower pressure in the polar region extending into North America, otherwise pressures are generally higher with an enhanced Atlantic anticyclone and a marked increase in the zonal flow over the Atlantic. This contrasts sharply with the trends of the 1960s (Lamb, Collison, and Ratcliffe, 1973) which were characterized by excessive blocking in the mid-latitude bands.

Turning to the seasonal maps (Figures 16, 17, 18 and 19) we see the winters were largely responsible for the features of the annual chart. The very marked anomalous Icelandic low and the increased Atlantic high together with the high pressure area in the Ukraine/Black Sea region combine to produce a very enhanced Atlantic westerly flow. This has been a dominant feature of recent winters in the British Isles and northern Europe. The map of difference of mean spring pressures retains some of the winter features with the enhanced Atlantic flow occupying a more northerly position but with negative differences over Greenland. The positive winter anomaly in the Aleutians region is reversed in sign and becomes a significant (−5 mb) low-pressure difference. The mid Atlantic and British Isles are more blocked than in the earlier period (1961-70).

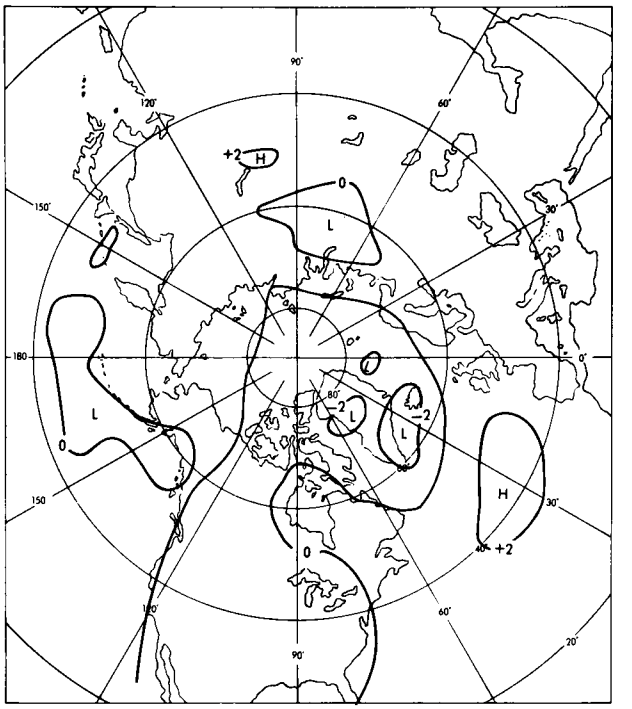

Figure 15. Mean-sea-level-pressure. Year.

Difference of averages, 1971-4 minus 1961-70, (mb).

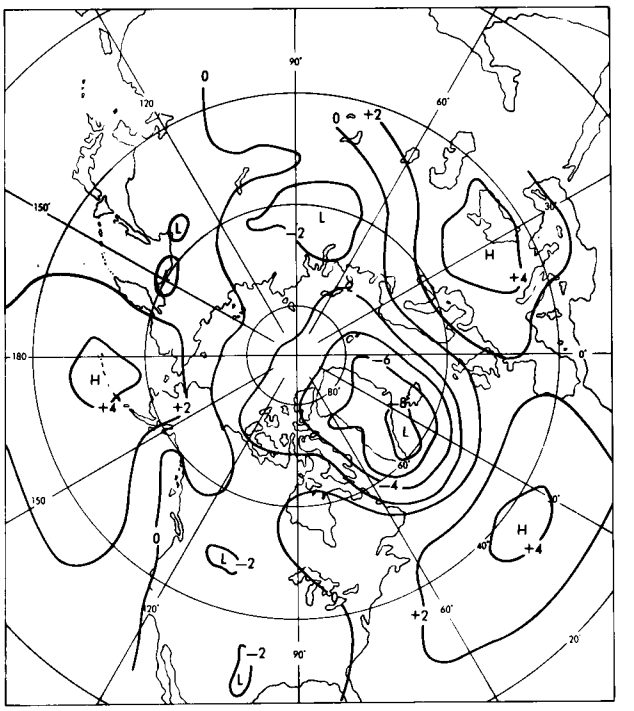

Figure 16. Mean-sea-level-pressure. Winter.

Difference of averages, 1971-4 minus 1961-70, (mb).

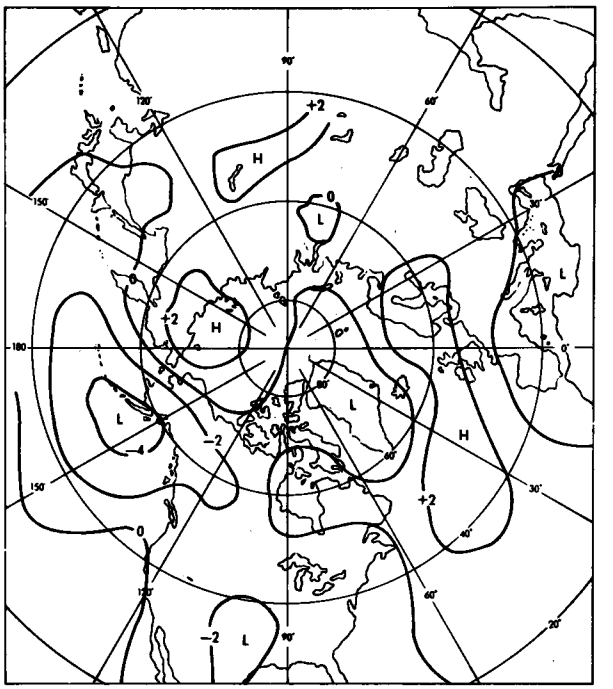

Figure 17. Mean-sea-level-pressure. Spring.

Difference of averages, 1971-4 minus 1961-70, (mb).

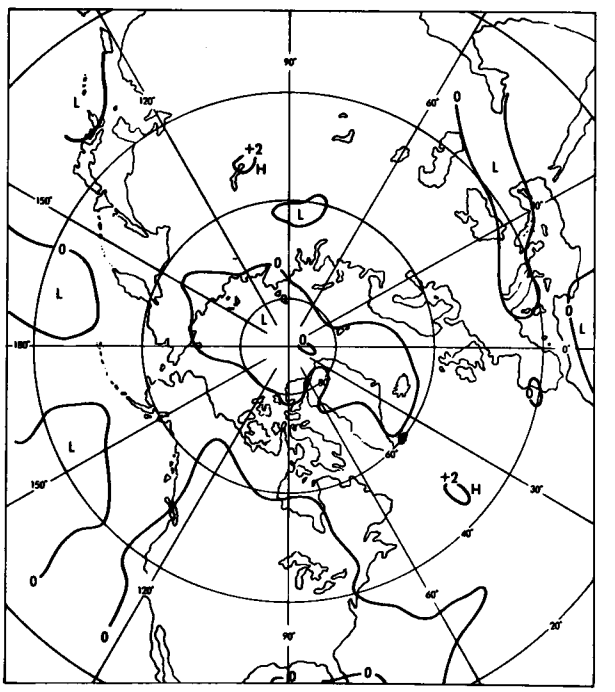

Figure 18. Mean-sea-level-pressure. Summer.

Difference of averages, 1971-4 minus 1961-70, (mb).

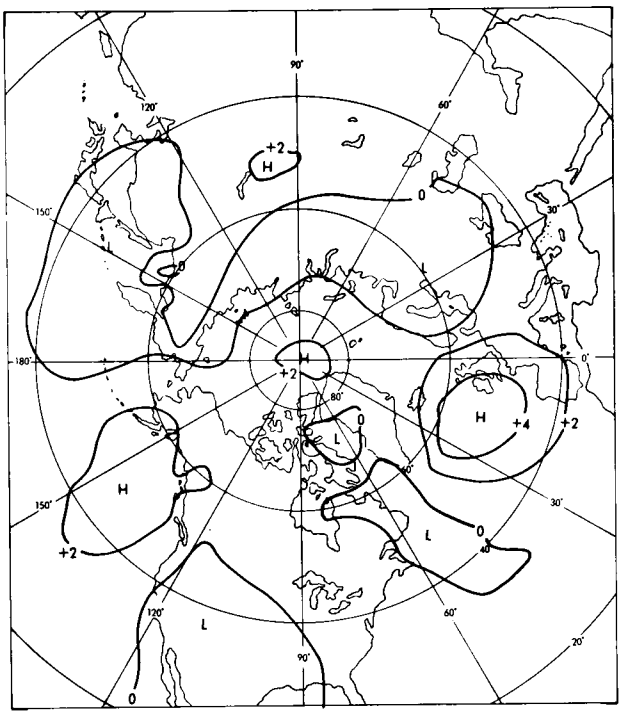

Figure 19. Mean-sea-level-pressure. Autumn.

Difference of averages, 1971-4 minus 1961-70, (mb).

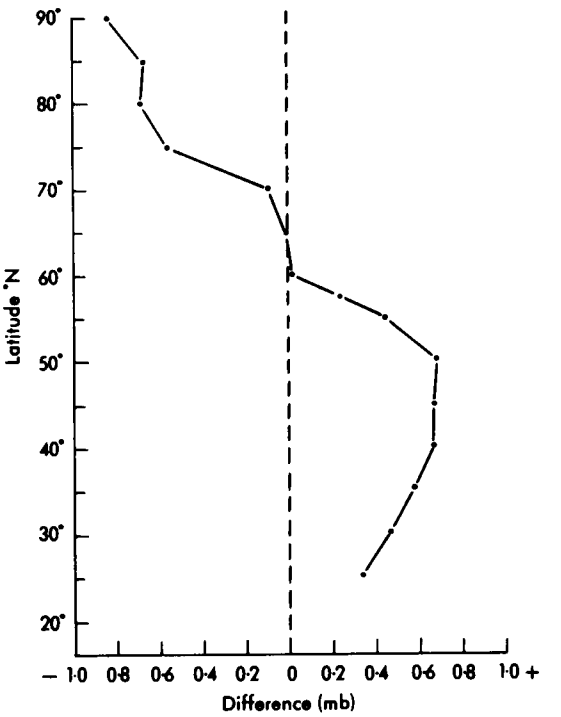

Figure 20. Mean-sea-level pressure. Year.

Difference of averages by latitude band, 1971-4 minus 1961-70, (mb).

The general picture for the summers is one of higher pressures in the northern temperate zone with lower pressure at the pole. The differences are rather small (generally not greater than 1 mb) and thus do not represent a significant change in summer pressure pattern. In the autumns we note a marked blocking anticyclonic anomaly to the west of the British Isles (+6 mb) with consequent enhanced northerly flow over the British Isles. Otherwise differences are generally small except in the Aleutians where a positive pressure difference is re-established. Figure 20 shows the annual mean differences between the 1971-74 and 1961-70 averages round 5° latitude bands. This graph shows a negative pressure difference near the pole which becomes positive at around 60°N, reaching a maximum between 40°N and 50°N. In terms of pressure gradient this implies an increase of gradient northwards of about 50°N with a slight decrease south of 40°N. This does not support an interpretation of increased blocking in temperate latitudes; in fact there is clear evidence of increased vigour in the circulation north of 50°N with little change, or some decrease of westerliness in the southern bands of the temperate zone. A comparison with 1000–500 mb thickness differences (Figure 6) averaged by latitude bands is interesting. There appears to be a correspondence between increasing zonal flow and reduction in meridional temperature gradient. This effect does not hold for year-to-year variations for the hemisphere or the Atlantic region and may justify further study on varying time scales.

7 ZONAL FLOW

Figures 21, 22 and 23 respectively show the zonal flow in 5° latitude bands for the northern hemisphere (whole year), northern hemisphere (winters), and Atlantic (winters), taking 5 year non-overlapping average departures from the 1900-73 normals in each case. Noteworthy features are the absence of any obvious trends in the band 50° to 60°N, a general falling trend in lower and higher latitudes since around 1930 and a remarkable upturn in the Atlantic westerlies for the winter seasons in the 1970s. For the UK westerlies (defined in this case as the mean pressure between 50°N, 0°W, and 50°N, 10°W minus the mean pressure between 60°N, 0°W and 60°N, 10°W) the general trends reflect those of the hemispherical averages (Figure 24). A noticeable feature is the greater variability over the last 40 years or so and the increase of pressure gradient in the 1970s.

Wind-direction frequencies based on analysis of grid-point pressures are shown in Figures 25 and 26 for the British Isles. Here we observe the general decrease in west-south-westerlies particularly in the winter months until the sharp upturn of the 1970s with a corresponding dip in the frequencies of north-westerlies.

8 BLOCKING AND SUB-TROPICAL ANTICYCLONES

Lamb (1974) has proposed that positive pressure anomalies in the temperate zones (observed by taking the departures of average atmospheric pressure at sea level over the years 1970–72 from the 1900–50 normal) represent increased blocking in the temperate zone. An analysis of the daily positions and central pressure of the Atlantic subtropical anticyclone and the number of days of blocking anticyclones in the mid-latitude band from longitude 80°W to longitude 10°E was therefore carried out to test Lamb's hypothesis for at least the Atlantic region. The method of defining and selection of the anticyclones is shown in Appendix 1. In

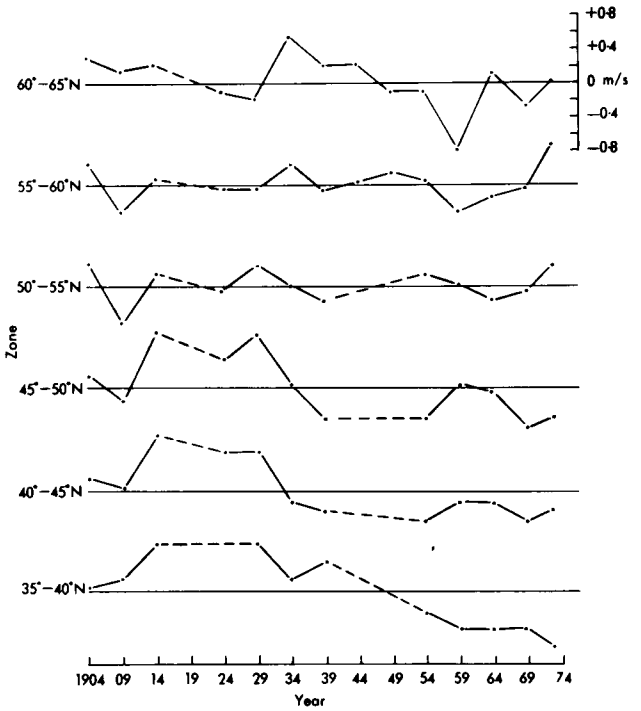

Figure 21. Zonal flow. Northern Hemisphere. Year.

5-year non-overlapping means of departures from 1900-73 averages, (m/s, ≈0.5 kn).

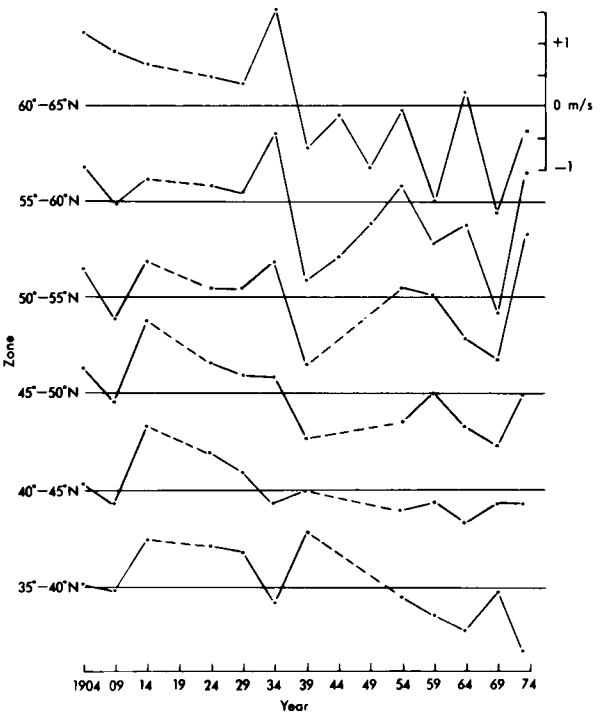

Figure 22. Zonal flow. Northern Hemisphere. Winter.

5-year non-overlapping means of departures from 1900-73 averages, (m/s, ≈0.5 kn).

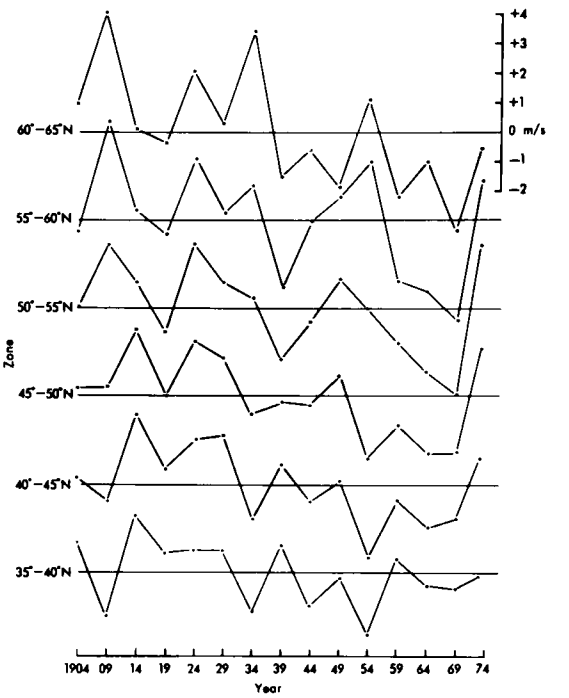

Figure 23. Zonal flow. Northern Hemisphere. Winter.

5-year non-overlapping means of departures from 1900-73 averages, (m/s, ≈0.5 kn).

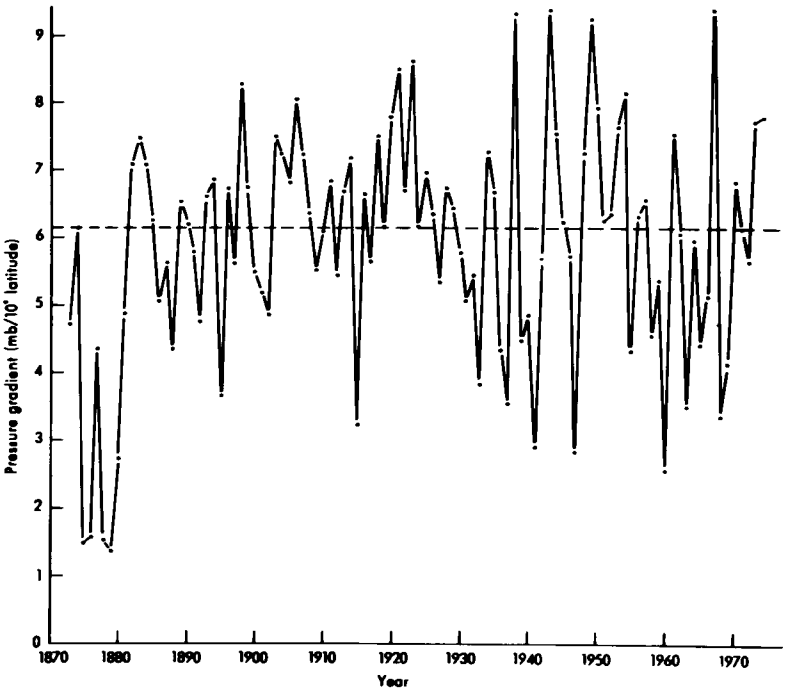

Figure 24. Pressure gradients over the British Isles 1873-1974.

Mean annual values, (mb/10° latitude).

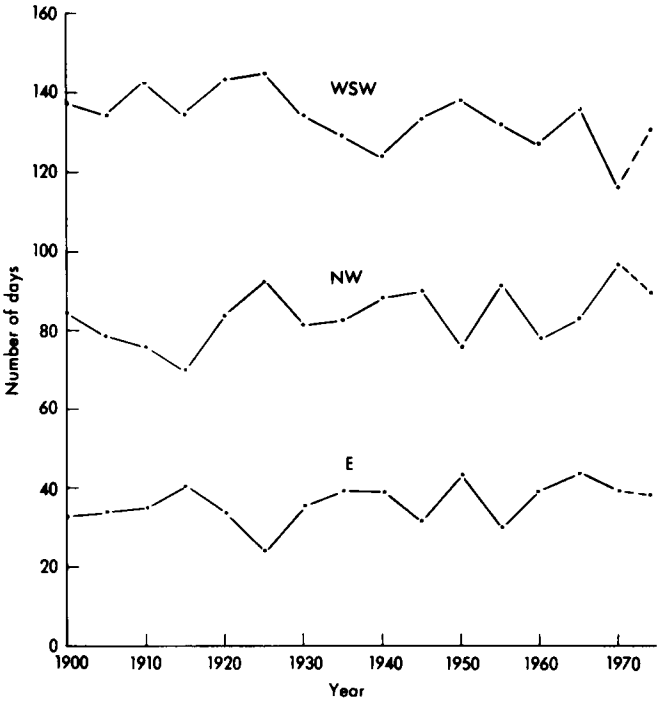

Figure 25. Wind direction frequencies. British Isles. Year.

5-year non-overlapping means of the number of days per year of wind with the specified directions 1895-1974 (the last entry is for 1969-73).

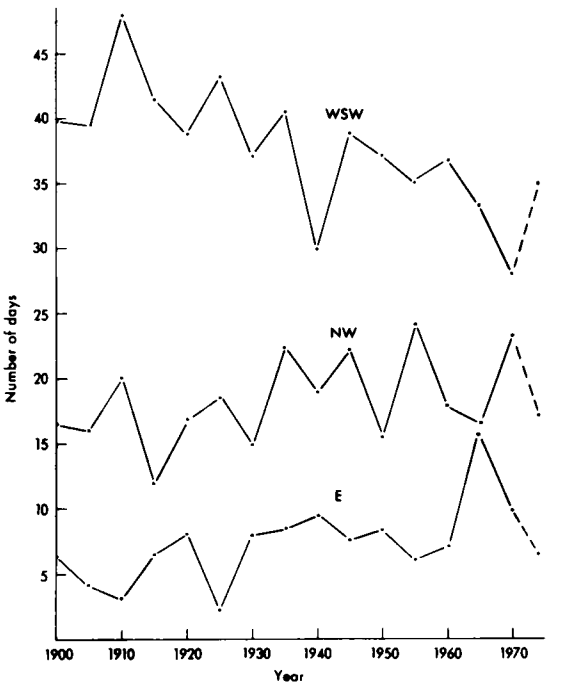

Figure 26. Wind direction frequencies for the British Isles. Winter.

5-year non-overlapping means of the number of days per year of wind with the specified directions 1895-1974 (the last entry is for 1969-73).

general the central position of the Atlantic subtropical high has moved further north in the second five years of the ten-year period studied. The February positions (Figure 27) are markedly different, there being some 6.5° of latitude difference between the mean monthly positions. The graph of Figure 28 shows that the average northward movement is only about 1° of latitude but this shift occurs for most months of the year.

Figure 29 shows the average number per month of days with blocking anticyclones in the region described above. Whilst there is considerable variability from month to month it is clear that there has been a marked decrease in the number of blocks in the winter seasons in the latter (1970–74) period and in fact only April, September and October show more blocking than the earlier period.

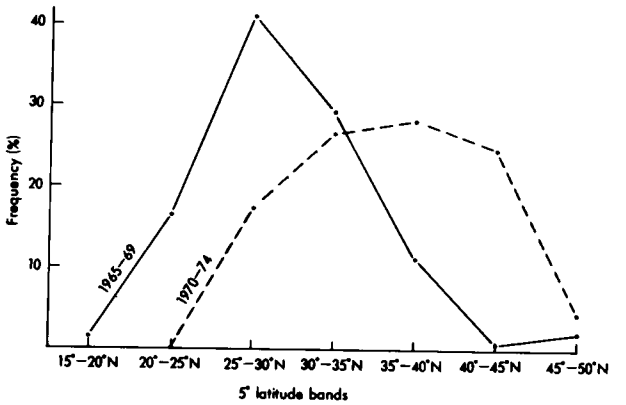

Figure 27. Atlantic subtropical anticyclone.

Percentage frequency of position of centre by 5-degree latitude bands in February 1965-9 and 1970-4.

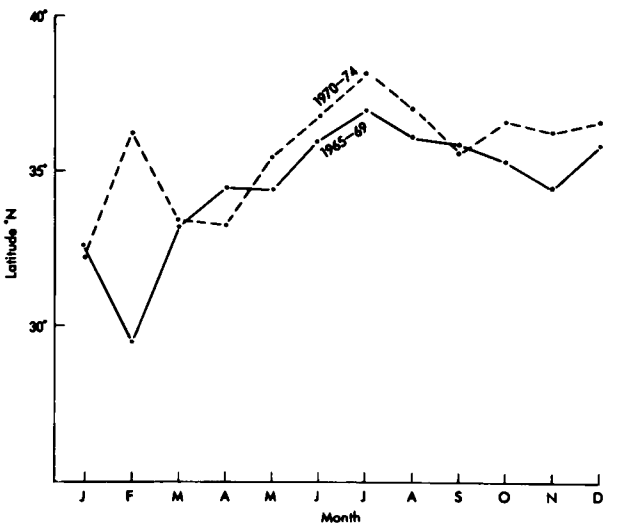

Figure 28. Atlantic subtropical anticyclone.

Average monthly latitude of centre, 1965-9 and 1970-4.

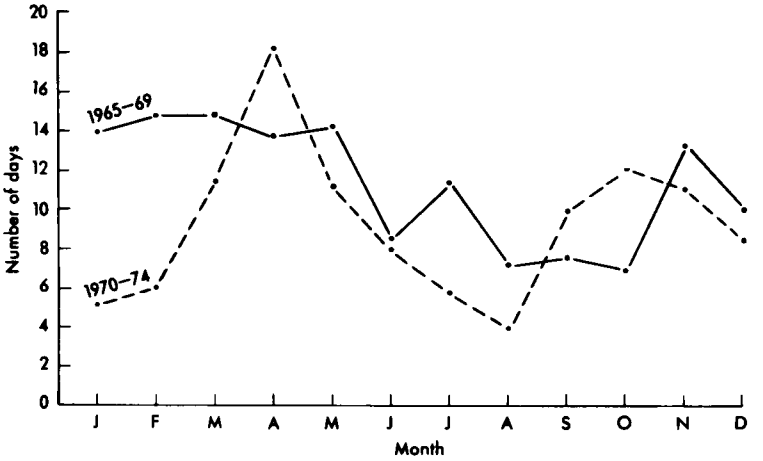

Figure 29. Average number of days per month in 1965-9 and 1970-4 with blocking anticyclones over the British Isles and North Atlantic mid-latitude band from 10°E to 80°W.

9 CONCLUSIONS

The last 5 years have shown some important differences from the 1960s. The latter were characterized by excessive blocking in temperate latitudes and a cooling trend over most of the northern hemisphere especially in middle and high latitudes. Some, but not all, of these trends have reversed in the 1970s. It is incontrovertible that over all latitude bands north of 50°N the zonal flow around the northern hemisphere has increased and this has been particularly evident in the Atlantic sector in winter. South of 40°N the zonal flow has decreased slightly. These findings are supported by the fact that, in the Atlantic sector, the centres of the subtropical high-pressure belt have moved slightly northwards (particularly in February) and the frequencies of blocking anticyclones have declined (especially in winter).

Along with this increase of westerly winds over the northern hemisphere north of 50°N has gone a marked decrease in the areas of Arctic sea ice and probably also of snow cover on land apart perhaps from an important area north of the Himalayas.

The Arctic has warmed, especially in the region from the Norwegian Sea across the Russian Arctic to near the Bering Strait. This result has been confirmed both by examining temperatures at high latitude stations and also from the changes in the mean values of 1000–500-mb thickness. Nevertheless, annual mean temperatures deduced from mean 1000–500-mb thicknesses show a net cooling over the hemisphere north of 40°N since about 1970 which amounts to an average annual value near to 0.2 deg. This has been especially marked south of 60°N where cooling deduced from thickness changes has been confirmed by surface temperature data.

Atlantic sea surface temperatures appear to have fallen from an exceptionally warm period in early to mid 1950s, but recent values do not appear to be remarkable when compared with values obtained over the last century or so.

It is possible that sea temperatures over the last few years are showing a lag effect. The strong blocking over Greenland in the 1960s resulted in persistent northeasterly winds over much of the Atlantic which led to some cooling of the near surface layers. This cooler water might well take several years to warm up and could be a contributory factor in keeping mid-latitude surface temperature and thickness down even though there has been an upturn in the strength of the westerlies. However, before this hypothesis is accepted it will be necessary to carry out further work.

Thus, to sum up, we have seen that the cooling trends of the 1960s have continued in the mid-latitude bands, but reversed in high latitudes. Areas of ice and snow have decreased and zonal flow increased in all latitudes north of 50°N.

ACKNOWLEDGEMENTS

The author wishes to thank Mr R.A.S. Ratcliffe for his help and guidance and all colleagues who assisted in providing and preparing data used for this study and in particular Mr R.A.H. Taylor for the snow area analysis and help with preparation of charts and diagrams, and Mr P. Collison for the bulk of the computer programming.

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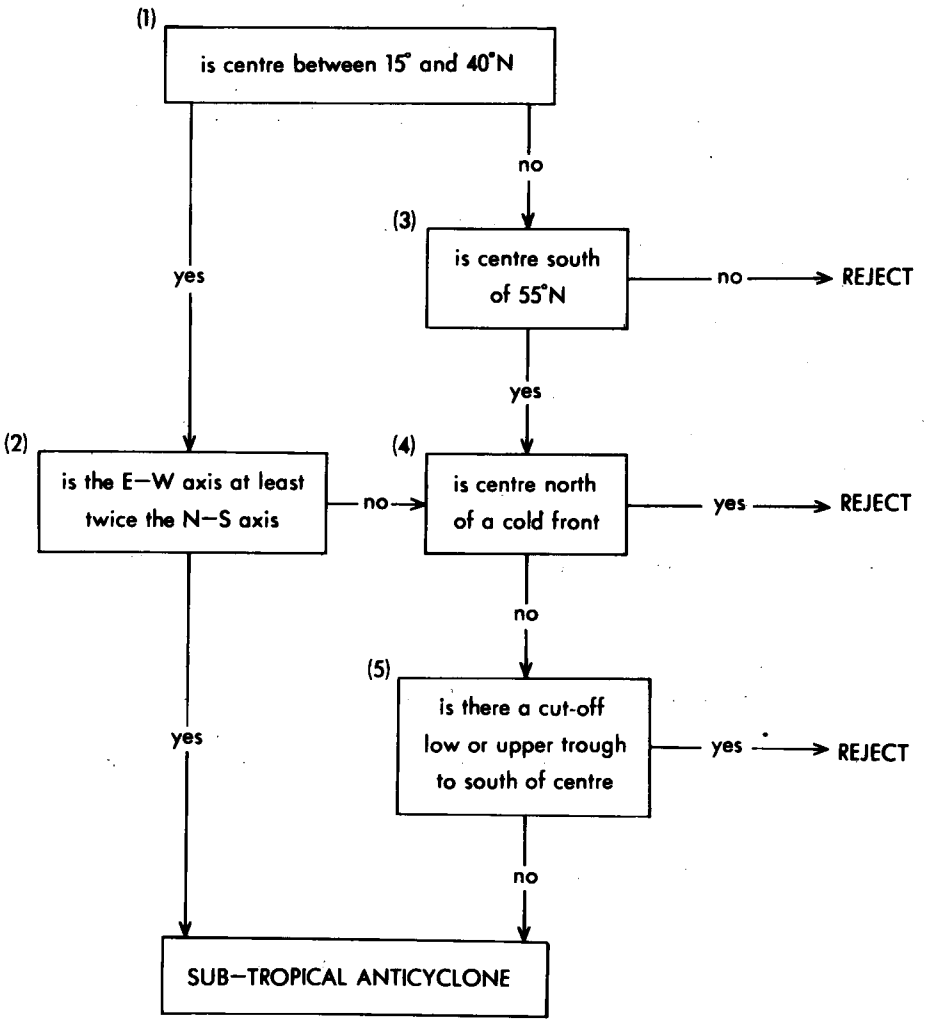
APPENDIX Ia

FLOW DIAGRAM FOR DEFINING SUB–TROPICAL ANTICYCLONES



(1) A combination of (1) and (2) is always a subtropical anticyclone.

(2) Axis must stop at front.

(3) No subtropical anticyclone north of 55°N.

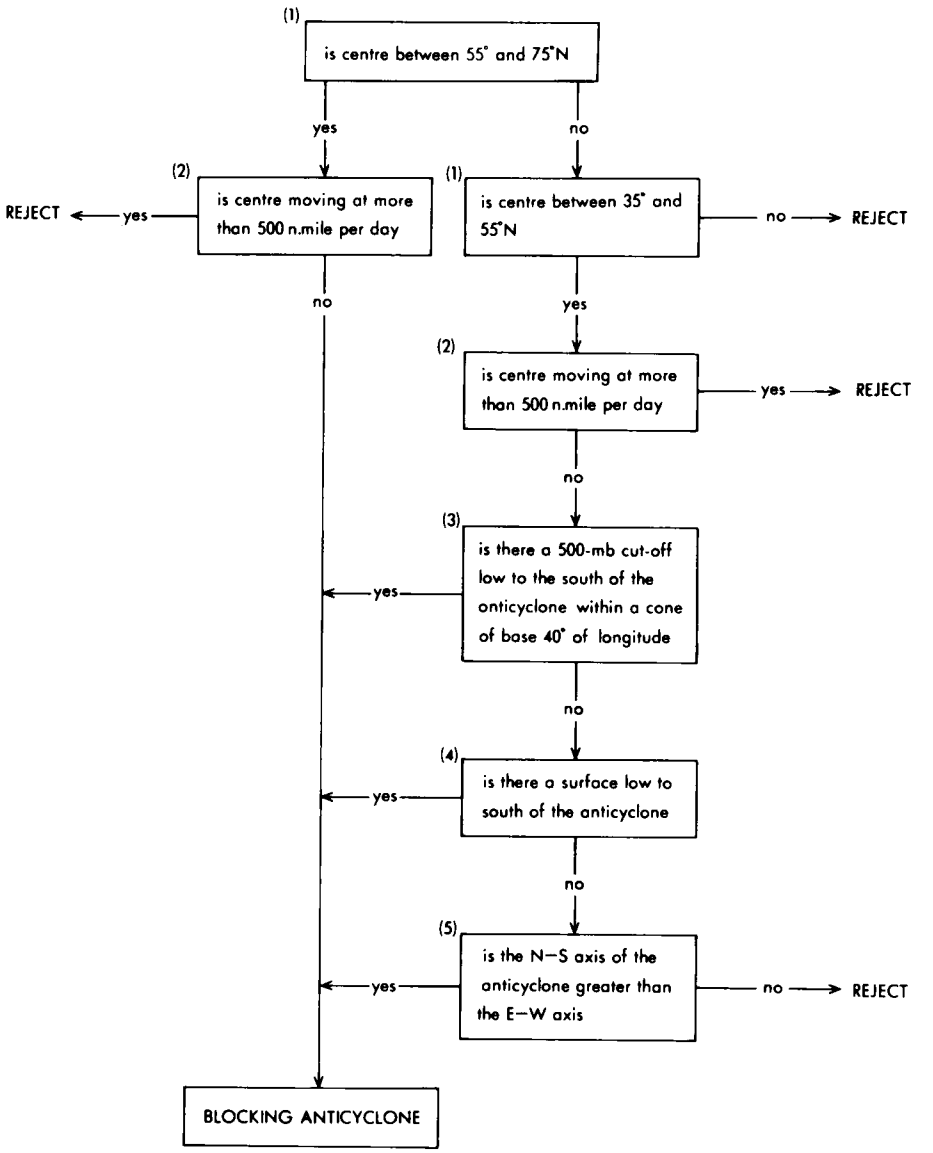
(4) Anticyclones to the north of cold fronts are either cold or blocking.

(5) Eliminates blocking anticyclones which are either diffluent or meridional in nature.

Problems are presented by the cell which is occasionally to be found over or near the south-west approaches to the British Isles (see 15 August 1966), and by the very borderline cases typically situated at about 45°-50°N in the central Atlantic (see July 1966).

APPENDIX 1b

FLOW DIAGRAM FOR DEFINING BLOCKING ANTICYCLONE



(1) Most blocks are found in these lots.

(2) Eliminates transitory cold highs and the occasional collapsing block.

(3) and (4). There are occasions when one of these is present without the other;(4) could probably be omitted, particularly if the limits of (5) were adjusted to include those highs with ratios of just less than one.

(5) Identifies meridional blocks. Distances should be measured in nautical miles at a distance, say, of 10 mb from the highest isobar, though fronts should not be crossed. Some blocking highs have north-south to east-west ratios of just less than one, so some discretion is called for.

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